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REVIEW OF BIOPHILIC DESIGN RESEARCH DEVELOPMENTS ON TRENDS, GAPS, AND FUTURE OPPORTUNITIES

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ABSTRACT

Biophilic design has become a prominent approach in contemporary architecture. It aims to enhance human health, well-being, and productivity by integrating natural elements into the built environment. However, despite its growing popularity, current biophilic design research and applications largely rely on universal principles and often overlook ecological and cultural contexts, particularly in non-Western, tropical, and urban regions such as Southeast Asia.

Aims: This study aims to examine the global development of biophilic design research by identifying major trends, research gaps, and future research opportunities.

Methodology and results: A summative content analysis was conducted on 90 highly cited articles published in indexed national and international journals between 2014 and 2024. The findings indicate that existing studies predominantly focus on direct and indirect experience of nature, while the experience of space and place, especially aspects related to cultural and ecological attachment to place, remains underexplored.

Conclusion, significance, and impact of the study: The findings highlight a critical research gap in context-sensitive biophilic design approaches. This study underscores the importance of developing regenerative biophilic design models that incorporate local wisdom, cultural identity, and ecological specificity. These models provide a foundation for future research and design practices that are both globally informed and locally responsive.

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1. INTRODUCTION

Biophilic design is a design theory that begins with the idea that humans love natural environments. Several studies have demonstrated that a connection to nature supports optimal human functioning. This connection enhances cognitive performance, including improvements in working memory, attentional control, cognitive flexibility, and restorative capacity. It also elicits positive physiological responses when compared to environments with limited or no exposure to nature [1], [2], [3], [4], [5]. Additionally, biophilic design minimizes the negative impact of urban life on the local micro-scale, allowing humans to increase their physical comfort and improve their health [6]. This approach is becoming increasingly relevant amid rapid urbanization and global modernization, which often separate humans from natural environments. Various studies have proven that nature can relieve stress, accelerate healing, promote positive moods, improve cognitive and academic abilities, reduce the risk of vascular disease, and mitigate the effects of ADHD and other childhood diseases [7], [8], [9], [10], [11]. These benefits explain the growing relevance of biophilic design in contemporary architectural discourse, particularly amid rapid urbanization and global modernization that often disconnect people from nature.

The development of biophilic design has produced several practical and philosophical frameworks. One such framework, often referenced in architectural research and practice, is the Three Categories and Fifteen Patterns of Biophilic Design by Browning and Ryan, consisting of Nature in Space, Nature Analogues, and Nature of the Space [12]. These patterns are commonly seen as practical design strategies applicable to the built environment. Additionally, based on recent research related to the framework's development, 18 elements have been identified, which are divided into three design approaches and primary elements: Nature Incorporation, Nature Inspiration, and Nature Interaction [13]. However, the development of the framework was influenced by the basic concept of the three experiences and 24 attributes of biophilic design by Kellert, which consists of direct experience of nature, indirect experience of nature, experience of scape and place [14]. This framework has a more conceptual and philosophical approach, emphasizing the depth of human relationships with nature in biological, psychological, and cultural contexts. Direct experience of nature focuses on direct physical contact with natural elements that are actually present in the built environment, such as light, water, plants, animals, weather, natural landscape, ecosystems, and fire. Indirect experience of nature refers to the

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representation of nature through artificial media or elements that simulate natural experiences, such as images of nature, natural materials, natural colors, simulating natural light and air, naturalistic shapes and forms, evoking nature, information richness, age change, and the patina of time, nature geometries, and biomimicry. Experience of space and place focuses on the spatial qualities and perceptions of place that evoke emotional and psychological experiences of nature, as well as cultural attachment. These include prospect and refuge, organized complexity, integration of parts to wholes, transitional spaces, mobility and wayfinding, cultural and ecological attachment to place [5]. Within the existing literature, it is important to distinguish between research on biophilic design and design studies that apply a biophilic approach. Design with a biophilic approach focuses on applying biophilic principles to specific architectural projects. In contrast, research on biophilic design examines the development and interpretation of biophilic frameworks within academic discourse. This study is positioned within the latter category.

However, a review of recent scientific literature reveals that most research still focuses on the first two categories: direct and indirect experiences of nature that positively impact humans. This is evident from the prevalence of themes such as lighting, natural ventilation, the role of indoor vegetation, natural materials, and optimal space design in the context of modern facilities in architecture and environmental design journals. Meanwhile, one dimension of the experience of space and place—Cultural and Ecological Attachment to Place—which includes cultural attachment, meaning of place, and local values, is still relatively neglected [13], [15]. This dimension is very important, especially in the context of non-Western societies with strong, unique value systems, cultures, and architectural traditions. Only a small amount of biophilic design research explicitly engages with cultural context or vernacular architecture. This indicates a continued reliance on universal design principles that do not sufficiently address local climatic, cultural, and environmental dimensions [15]. This limitation has been widely acknowledged in the literature. Critical reviews emphasize that biophilic design research often prioritizes generalized strategies over experiential and place-based interpretations of human–nature relationships [16], [17]. Empirical evidence from heritage and adaptive reuse contexts further demonstrates that meaningful biophilic experiences emerge when cultural identity becomes an integral part of the spatial experience, rather than being reduced to the mere insertion of natural elements [18].

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This literature gap is particularly significant in light of the potential contribution of traditional architecture to the biophilic design approach. Traditional architecture around the world, including in Southeast Asia and especially in Indonesia, boasts a variety of forms, meanings, and philosophies that align with biophilic design principles. Balinese Traditional Architecture, for example, is grounded in Tri Hita Karana philosophy, which emphasizes harmony between God, humans, and nature. This philosophy reflects long-standing principles that align with contemporary interpretations of biophilic design [19]. This philosophy is consistently enacted through social norms and spatial practices in Bali. There, cultural regulations and planning approaches reinforce balanced relationships among spiritual, social, and ecological dimensions. Environmental conservation is an integral part of everyday life [20], [21]. However, these values tend to be applied to architecture as cultural sustainability without being scientifically assessed for their positive impact on humans. Traditional architecture is valued for its nature-based approaches, and researchers believe it can positively impact its users. In this context, this study aims to explore and map the evolution of the global trend in biophilic design research and determine if special attention is given to biophilic design approaches based on culture and ecology.

This article focuses on biophilic design approaches based on culture and ecology. This article uses a summative content analysis of 90 highly cited articles from Scopus, Web of Science (ESCI), and DOAJ-indexed, internationally reputable journals to examine global trends in biophilic design research. This research has three main objectives: first, to identify the main trends in the development of biophilic design research through literature analysis; second, to find research gaps related to the connection between culture and space in biophilic design; and third, to provide directions for future research opportunities based on local cultural approaches in biophilic design. This research is expected to expand the scientific horizons in the field of biophilic design and encourage more inclusive, contextual, and regenerative design approaches in the future. This is important because current and future challenges concern not only ecological sustainability, but also the sustainability of cultural identity and the psychological well-being of communities. Thus, biophilic design can evolve from an aesthetic approach into a holistic, transformative design strategy for global urban communities.

2. RESEARCH METHODOLOGY

This research employs a systematic literature review (SLR) approach, which is conducted through

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transparent, explicit, and reproducible procedures, to identify, evaluate, and synthesize the relevant body of published research in the field of biophilic design [22]. Following established review protocols, the selected publications are systematically screened and analyzed to ensure methodological rigor and to minimize reviewer bias. The extracted literature is subsequently examined using summative content analysis, which involves counting and comparing keywords or manifest content. This is followed by interpreting the underlying contextual meanings to characterize dominant themes, research directions, and conceptual emphases within the field [23]. To further support a structured overview of the field's intellectual structure and global development, the review is complemented by analytical procedures that identify patterns and relationships across the literature. These procedures are consistent with established approaches to mapping research domains [24].

This study adopts a non-reactive research approach, utilizing existing or archival data and content analysis to obtain findings without direct engagement with research subjects, ensuring an unobtrusive data collection process [25][26]. Thus, non-reactive research is related to the systematic literature review (SLR) method in that they both take an indirect approach to data. The summative content analysis method evaluates trends, strategies, and thematic gaps in biophilic design research globally. A total of 90 scientific articles were used as primary sources selected from Scopus, Web of Science (ESCI), and DOAJ databases, published between 2014 and 2024. The selection process applied the following criteria: (1) the articles must explicitly discuss biophilic design or biophilia in relation to the built environment; (2) the articles must be indexed in reputable databases; and (3) the articles must be widely cited or considered influential in advancing the discourse. Keywords such as "biophilic design," "biophilia," "framework," "culture," "sustainability," and "traditional architecture" were used to ensure thematic relevance

The initial stage involved filtering articles based on their titles and abstracts. Articles that were not directly relevant to the biophilic design framework or that did not discuss its relationship with the built environment were excluded. The remaining articles were categorized based on their focus: (1) development of the biophilic design framework; (2) relationship between biophilic design and sustainability; (3) application in contexts, such as building facilities (e.g. schools, offices, hospitals), urban spaces, etc.; (4) intersections with cultural or ecological contexts. This analysis involves identifying the content of the discussion in the article, taking the core meaning, and capturing it in codes and categories according to the knowledge you want to capture. For example, you could identify the design strategies used or the impacts of applying

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these strategies. After completing the Excel data, the next step is to code the data based on two main theoretical frameworks often used in biophilic design studies: 15 Patterns of Biophilic Design [12] and 24 Attributes of Biophilic Design [5]. Both frameworks categorize biophilic experiences into three broad groups: direct experience of nature, indirect experience of nature, and experience of space and place. Coding was done with the help of JMP software, which allows for systematization in theme tagging, visualization of analysis patterns, and identification of relationships between variables.

The analysis focused on three dimensions: (1) the frequency with which themes occurred across the 90 articles; (2) the contextual application of biophilic principles in different building typologies and cultural settings; and (3) the benefits associated with each strategy, such as well-being, sustainability, health, and spatial connectivity. To enrich the findings, a thematic correspondence analysis was conducted to examine the relationships between biophilic strategies and their reported outcomes. Additionally, a bibliometric analysis was conducted using VOS viewer on a larger dataset of 281 articles from ScienceDirect to validate thematic patterns and identify under-explored concepts, particularly those linking biophilic design with vernacular and traditional architecture and cultural identity. By integrating SLR, summative content analysis, and bibliometric validation, this methodology not only maps current research trends but also provides a robust foundation for identifying knowledge gaps. This enables the study to propose directions for regenerative biophilic design models that are globally informed yet locally rooted. This is particularly relevant for tropical and culturally rich contexts, such as Southeast Asia and Indonesia.

3. RESULTS AND DISCUSSION

This study aims to identify the main trends in global biophilic design research through a summative content analysis of 90 scientific articles indexed in Scopus, Web of Science (ESCI), and DOAJ over the past ten years (2014–2024). Figure 1 shows that the most dominant topics in the literature are the relationship between biophilic design and sustainability (34%), biophilic design theory development (17%), urban context (14%), and application in facilities such as schools (10%), offices (10%), residential buildings (11%), and healthcare facilities (4%). These findings suggest that biophilic design remains closely tied to sustainability efforts and the design of modern buildings, especially on an institutional scale. However, topics addressing local cultural values, place attachment, or vernacular architectural contexts remain rare in the development

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of biophilic design theory.

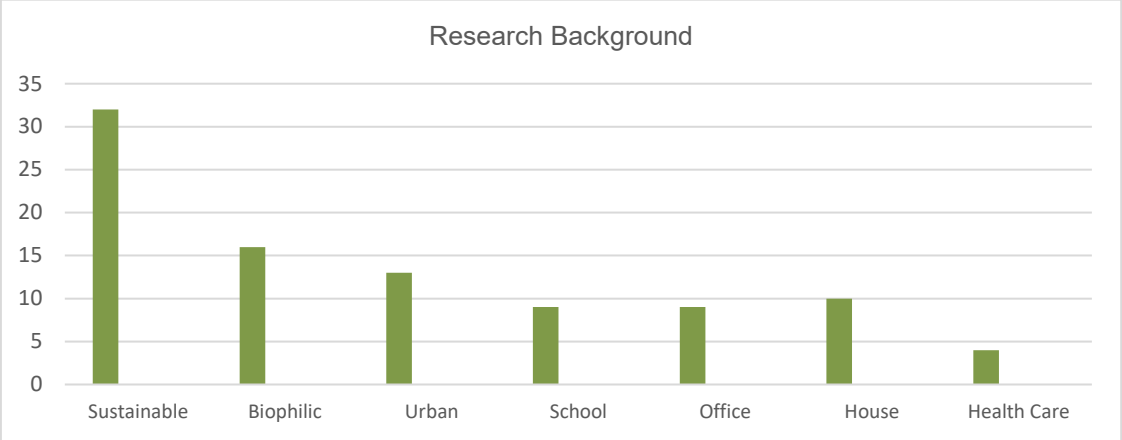

Fig. 1 Biophilic design research background
Source: Literature Review, 2024

This aligns with the findings of Li et al. [15], who emphasized the scarcity of studies explicitly linking biophilic design to cultural contexts, despite the importance of this dimension in developing more contextual and adaptive design strategies.

In addition to mapping research topics, this study also identified the geographical distribution of biophilic design publications. As shown in Figure 2, the results reveal a high

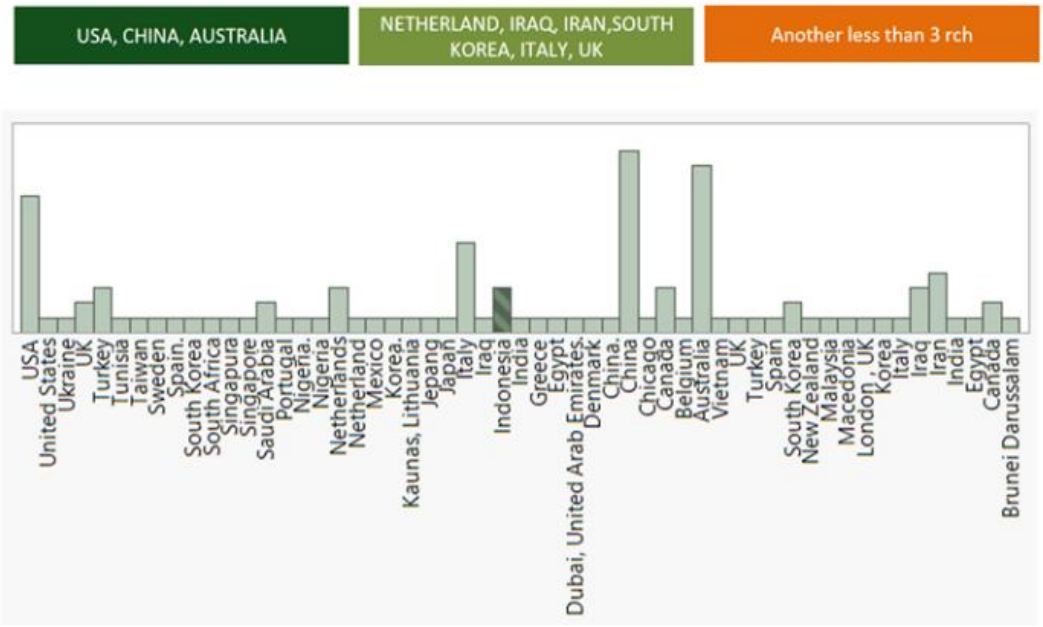

Fig. 2 Country distribution of biophilic design research
Source: Literature Review, 2024

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concentration of research in countries such as the United States, China, and Australia. Some Western European countries, such as the Netherlands and the United Kingdom, also made significant contributions. Meanwhile, countries in Southeast Asia, including Indonesia, have limited involvement as a study context. This indicates the low level of attention given to the application and development of biophilic design in tropical and culturally local regions, which have great potential for further exploration [13].

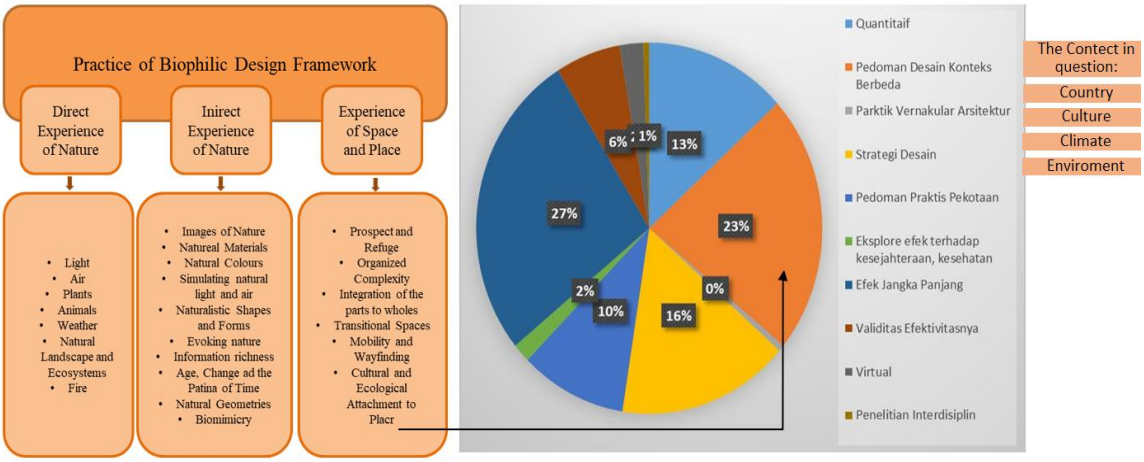

Fig. 3 Future research of biophilic design
Source: Literature Review, 2024

This study also identifies future research directions based on an analysis of the "Suggestions for Future Studies" section listed in the reviewed articles. These results are visualized in Figure 3 the "Future Research Pie Chart." As can be seen from the graph, future research proposals largely focus on the need for quantitative, method-based exploration (27%) and the development of design guidelines for different cultural contexts (23%). Other important themes include developing design strategies (16%), providing practical guidelines for urban areas (10%), and emphasizing the empirical evaluation of the effectiveness and validity of designs (6%). Based on this data, 23% of the 90 articles recommend design guidelines for different contexts. Thus, future research opportunities are expected to align with these recommendations. These contexts differ in terms of countries, cultures, climates, and environments. These conditions further emphasize the urgency of such research connecting biophilic design with local contexts, particularly traditional architecture. Researchers such as Kellert [5] and Beatley [7] have emphasized the importance of developing a biophilic approach that is "locally rooted and ecologically attuned." However, implementation and exploration in non-Western contexts remain highly limited in practice.

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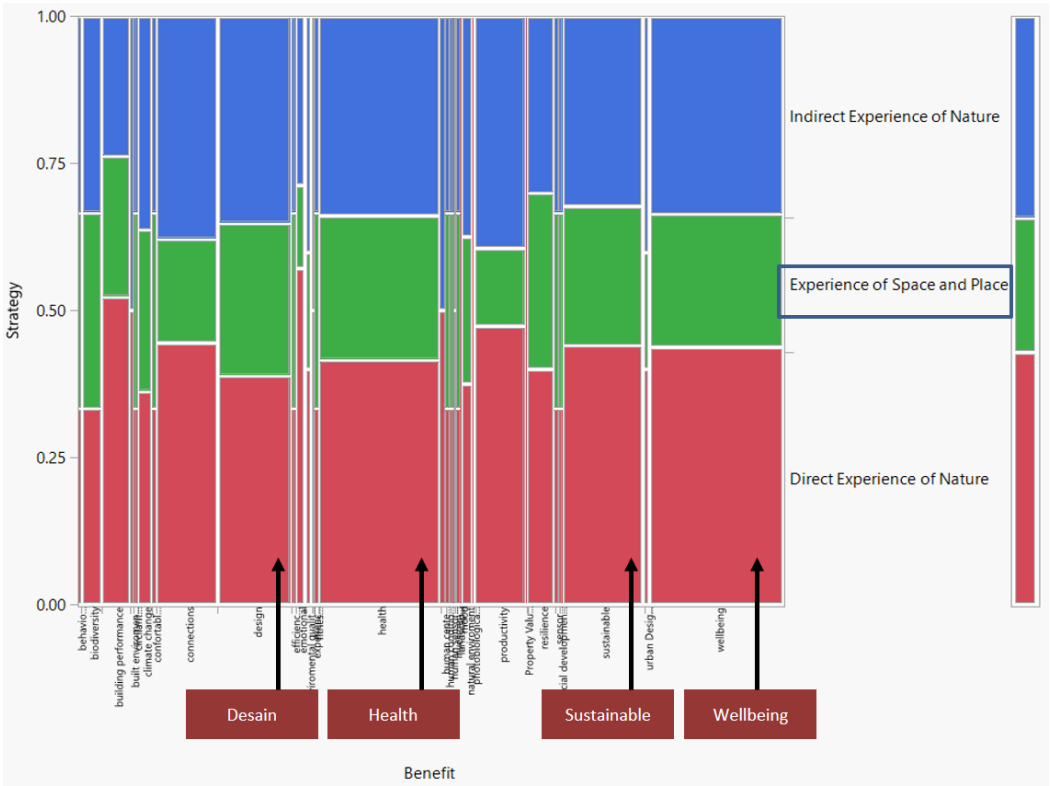

Fig. 4 Gap of biophilic design research
Source: Literature Review, 2024

This study aims to reveal research gaps related to the connection between culture and space in biophilic design. This connection is examined through a content analysis of biophilic design strategies, patterns, and attributes. These are divided into three main categories: Direct Experience of Nature, Indirect Experience of Nature, and Experience of Space and Place. A thematic correspondence approach was used with JMP software to map the relationship between design strategies and the benefits of biophilic design. The results of the analysis were visualized in a mosaic plot showing the contribution of each category to various benefits. The most dominant benefits were well-being, sustainability, health, design guidance, and spatial connectivity (Figure 4). Based on this visualization, the most commonly used strategies for achieving the benefits of biophilic design were found to be in the direct and indirect experience of nature categories. These strategies include the use of natural light, ventilation, vegetation, natural sounds, natural materials, and visual representations of nature. These strategies dominate research examining the influence of biophilic design on human performance, spatial comfort, and design effectiveness [5], [12]. Meanwhile, the third category, Experience of Space and Place, which includes elements such as refuge, prospect, organized complexity, transitional

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spaces, and cultural and ecological attachment to place, remains understudied.

The results show that the direct and indirect experience with nature is the most dominant theme in contemporary studies, mainly through elements such as natural lighting, indoor vegetation, and natural airflow. However, one important finding of this study is the lack of attention to the "experience of space and place" dimension, particularly the "cultural and ecological attachment to place" attribute. This attribute plays an important role in strengthening local identity, emotional attachment to place, and cultural sustainability [27]. In addition, geographical mapping revealed that most studies originated from one country. This study shows that regional disparities are related to cultural contexts. Traditional architecture in tropical and culturally rooted regions has great potential for developing a more contextualized biophilic approach. This indicates a critical research gap in the integration of cultural symbolism, spatial hierarchy, and ecological meaning into design frameworks, which has the potential for further exploration.

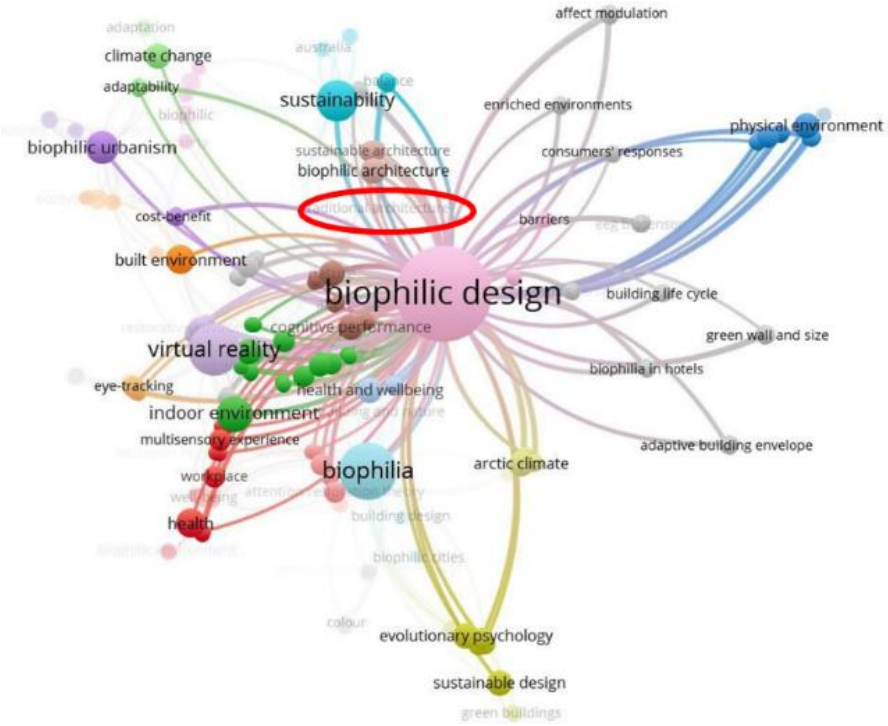

Fig. 5 Vos-viewer analysis of biophilic design research
Source: Vos Viewer, 2024

This gap is further reinforced by the results of a bibliometric analysis conducted using VOS-viewer on 281 articles retrieved from the ScienceDirect database using the keywords "biophilic," "biophilic design," or "biophilic principle." The network mapping results show that the concepts

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most frequently associated with biophilic design are sustainability, health and well-being, the indoor environment, virtual reality, cognitive performance, and the urban context. Meanwhile, concepts such as "traditional architecture," "vernacular environment," and "cultural heritage" do not appear as main nodes and only appear at very low frequencies. These results indicate that the connection between biophilic design and local culture and space has not yet become a primary focus in the international scientific discourse on biophilic design, both empirically and bibliometrically. Thematic correspondence analysis and bibliometric analysis reveal that the dimension of cultural and ecological attachment to place has not been extensively researched despite its significant potential for developing more locally rooted regenerative design strategies.

The limited attention given to cultural and ecological dimensions contrasts sharply with the potential of traditional and vernacular architecture. Balinese traditional architecture comprises spatial rules, such as *Lontar Asta Kosala-Kosali*, *Asta Patali*, that have been passed down from generation to generation by the Balinese people. These rules are broad in nature and cover all aspects of Balinese life. Balinese traditional architecture is influenced by basic concepts that impact its spatial values [28]. One such concept is Tri Hita Karana, meaning "the three causes of wellbeing," rooted in the harmony of three relationships: (1) *Parahyangan*, the relationship with God, (2) *Pawongan*, the relationship with humans, and (3) *Palemahan*, the relationship with the environment [19]. These concepts are translated into traditional housing designs that demonstrate connectivity with God, humans, and nature. This concept aligns with biophilic design, an approach that aims to connect building occupants more closely with nature [29]. This harmony is reflected in the philosophy of human-nature relationships, place attachment, the use of local materials, and the creation of open spaces that stimulate sensory and emotional connections with the environment. Traditional architecture is designed to naturally nurture humans to live in harmony with the universe, both individually and collectively [30]. This forms an important foundation for the contextual biophilic design approach, which considers local culture, climate, and ecological conditions. As Kellert and Calabrese state [5], human experiences with nature are not universal, but are influenced by geographical and cultural conditions. Therefore, biophilic design cannot be separated from the local roots of the place where it is applied. In this context, traditional architecture, which has proven adaptive and responsive to the local environment, can serve as an important source of learning and inspiration for developing more relevant and sustainable biophilic design models.

Based on previous studies, three biophilic design articles focusing on its relationship with

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traditional/vernacular architecture were identified. One of these articles, "Biophilic Design Features in Vernacular Architecture and Settlements of the *Naxi,*" discusses the relationship between biophilic design and vernacular architecture in the context of Naxi architecture and settlements in China [15]. The second article is "An Evidence-Based Assessment of Biophilic Interior Design in a Traditional Context: The Case of the Kingdom of Saudi Arabia," which evaluates the application of biophilic design in traditional architecture in the Kingdom of Saudi Arabia, focusing on integrating traditional architectural values with biophilic design features [31]. The third article, "Investigating the Application of Biophilic Design Principles in the Traditional Pol Houses of Ahmedabad with a Case Study on Mangaldas Ni Haveli," explains how Pol houses in Ahmedabad, naturally integrate biophilic elements such as natural lighting, ventilation, and the use of natural materials, as part of the city's cultural and architectural heritage [32]. These studies demonstrate that biophilic design approaches can be identified in traditional buildings through observation, document review, in-depth interviews with stakeholders, and other contextual methods. These results suggests that biophilic design can be linked to traditional and vernacular architecture to create a more contextual design approach. Biophilic design research has achieved significant global visibility, but it remains dominated by universalist and functional strategies. The lack of emphasis on experience of space and place, particularly cultural and ecological attachment, represents both a limitation and an opportunity. Addressing this gap could transform biophilic design into a regenerative model that incorporates local knowledge, preserves cultural identity, and enhances ecological resilience. In tropical and rapidly urbanizing regions, such as Southeast Asia, integrating these elements is essential for developing design strategies that are sustainable, socially transformative, and culturally relevant.

4. CONCLUSION

This study addresses the need to clarify global research trends, gaps, and future directions in biophilic design. It does so by systematically reviewing 90 scientific articles published between 2014 and 2024. The findings demonstrate that current biophilic design research predominantly focuses on direct and indirect experiences of nature, particularly through design strategies related to lighting, ventilation, vegetation, and natural materials, primarily in urban and modern architectural contexts. In response to the second research objective, the review reveals a significant research gap: limited attention to the experience of space and place, particularly cultural and ecological attachment to place. This gap is further reflected in the

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underrepresentation of non-Western regions, such as Southeast Asia and Indonesia, despite their rich traditions of nature-based and culturally embedded architecture. In addressing the third objective, the study highlights the potential of vernacular and traditional architecture, such as Balinese traditional architecture guided by the Tri Hita Karana philosophy, as an important source for developing more contextual and regenerative biophilic design frameworks. Overall, this review contributes to biophilic design scholarship by emphasizing the need to move beyond universal design strategies toward research approaches that integrate cultural identity, ecological context, and place-based values in future studies.

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